Intelligent Person-Centric Services for Smart Environments: 'Where are you?'

Chris NUGENT[1], Matthias BAUMGARTEN[1], Maurice MULVENNA[1], David CRAIG[2], Franco ZAMBONELLI[3], Marco MAMEI[3], N BICOCCHI[3], Kevin CURRAN[1]

Faculty of Engineering, University of Ulster, Northern Ireland[1]
Belfast City Hospital/Queen's University of Belfast, Northern Ireland[2]
Università di Modena e Reggio Emilia, Italy[3]

Abstract. This paper introduces novel techniques for person-centric services in pervasive spaces. These are focused on the support of independent living spaces for people with mild cognitive impairment, for example. We demonstrate from a technical perspective, how such services could be realised based on the emerging concepts of a distributed network of knowledge, facilitating dynamically composable and flexible service provision that engenders service continuity - beyond the home for example.

Keywords. Person-centric services, computational fields, smart environments, service continuity

Introduction

As the population continues to grow, society is faced with the challenge of supporting those within the community who still remain within their own homes and are not fully independent. Independence can be regained by a number of stakeholders providing support – healthcare providers may visit the home to administer medication and monitor vital signs, close members of the family may be responsible for the reminding of simple daily activities and neighbours may offer the comfort of security by being in close proximity. It has become more and more widely appreciated that the application of technology within the home environment can provide, to a certain extent, a degree of independence which may have previously been provided by one of the aforementioned stakeholders. The major benefits of deployment of technology in such a manner is the potential to extend the duration a person remains in their own home and thus avoids institutionalisation.

Although technology can promote independence and indeed impact positively upon a patient's quality of life, detrimental effects can also be witnessed if reliance upon the technology reaches a level where the patient will not leave their own home in fear of losing the support once outside of the home. Taking this into consideration it becomes necessary to ensure the technology has a degree of portability and continuity of service to ensure its support both inside and outside of the home environment. This requires the continuum of services from within the home to places like supermarkets, hospitals and banks i.e., places patients are likely to visit.

1. The Need for Intelligent Services

In our current work we have addressed the requirement of portability and continuity of service from a number of perspectives. In the first instance we have undertaken a needs assessment of a likely cohort of patients who would benefit from availing of such a service – mild dementia sufferers. We have translated these needs into an identification of service delivery requirements within the home environment and subsequently extended these services to one key service for use outside the home. We have subsequently demonstrated, from a technical perspective, how such a service could be realised based on the emerging concepts of a distributed network of knowledge.

1.1. Requirements from a Mild Dementia Perspective

Patients with dementia are roughly four-times more likely than those without dementia to require institutionalized care. In the UK alone it is estimated that more than 750,000 people are affected by dementia[1]; and by 2050 there will be about 1.8 million people with dementia in the UK due to steady increases in the numbers of older people. Similar figures at European and Global levels are also witnessed. By providing home support at an early stage is ultimately likely to be cost effective, particularly when individuals live alone – a situation involving roughly a third of dementia sufferers at any one time. Within the home environment it has been identified that technology can be used to support a wide range of tasks. These can be categorised as follows:

- cognitive reinforcement – helping people to remember
- social reinforcement – helping maintain social contact
- functional – performing daily life activities
- security – enhancing feelings of safety.

Although techniques such as notebooks and diaries have addressed some of these needs, evolving technical solutions offering a form of cognitive prosthetic are making a positive impact.

1.2. Supporting independence beyond the living environment

To avoid reducing the net impact of cognitive prosthetics introduced within the living environment requires ensuring a continuum of service i.e., the service provided is not lost once the patient leaves their home. If we consider the typical requirements a typical dementia patient would exhibit a key requirement would be spatial orientation reinforcement i.e., continuation of support from their network of family/friends/carers when they leave the home. An example of when such a service would be required would be in instances of the person not being able to find their way home or to remember why they have left the house, for example, to attend an appointment.

From a technical perspective addressing the problem of spatial reinforcement is largely complex for a number of reasons. In the first instance the service must be delivered to available stakeholders at a number of levels of granularity. For example, provision of service with those in close proximity perhaps in the same building or street, or those in the same town or alternatively those who may be simply ‘available’ to offer support but may be located within a larger geographical area. A secondary issue for

[1] www.alzheimers.org.uk

consideration is *are the people within proximity able to support the patient*? For example a patient who requires some advice as to why they have left the house may only be able to receive support in this instance by a family member who has access to the patient's daily agenda. On the other hand, if the stakeholders' prosthetic raises an 'emergency suggestion for intervention' message then the appropriate stakeholder who can be contacted should be made aware of the situation.

If we assume in the first instance that communication between the patient's cognitive prosthetic and the stakeholder's prosthetic can be established the problem becomes one of information management within a networked environment addressing the dynamic positioning of the patient and stakeholders. This suggests that the requirements of the technical service should provide for the following:

- Situation awareness – to identify the positioning of the patient and stakeholders
- Self organising – to identify the closest stakeholder in instances of alarm
- Autonomy – the ability of the service to dynamically self adapt
- Knowledge management – the ability to infer from the knowledge within the network

Based on these criteria the following sections provide a description of a technical realisation for these issues based on a knowledge network paradigm.

2. A Distributed Network of Knowledge

One of the challenges for future smart environmental infrastructures is the need for them need to reason about their situation and to understand their own behaviour. To do this they are required (both at the level of individual components and as a whole) to be introspective and reflective, and to feed back the results of these processes to be used to improve performance. While this provides the knowledge with which they can, eventually, manage and configure themselves it also makes them more self-aware or in short it makes them smarter. However, in order to get 'smarter', the environment, its entities and services need some form of properly represented, well correlated and widely accessible repository that leads to the concept of a knowledge network.

Within the concept of a knowledge network there is a basic need for the expressive and flexible means to promote context-awareness. Smart environments, their components and services need to have awareness of situations with differing degrees of granularity [1]. There is a requirement for some form of computational model of context processing as presented in [2] that orchestrates context stimuli and components in a coherent representation. Additionally, there is a requirement for some way of gauging the quality of contextual information objectively as it is gathered, as from the Quality of Context mechanism of Buchholz *et al.* [3]. As described in [3] any contextual information has associated with it parameters including precision of information, correctness probability, trust worthiness, resolution and regency. Simply said, contextual information cannot be reduced to a trivial set of data to be accessed by components, but requires some higher-form of organization.

As depicted in Figure 1 (a), knowledge networks have to provide a *virtual view* of the environment they are operating in to allow the *concept of interest* to adapt to changing conditions. In our current work this is based on a "Computational Fields" perspective that can be represented through knowledge networks [4]. In summary let us assume that:

- the presence of a person in an environment (e.g., a shopping mall) can be translated into a gravitational field ***F=(name, force)*** propagated across the network infrastructure.
- this can be automatically updated to reflect current position of the person.
- the resulting distributed data structure is a sort of **distributed network of knowledge** expressing:
  - -Who one is.
  - -Where, in which direction and how far, one person is from another (Figure 1 (b) and (c)).

Considering the problem from an additional perspective, contextual information cannot be simply considered as local and locally available to components and services. For a satisfactory adaptive orchestration of distributed activities (whether this is intended to be the orchestrated configuration of individual components or the coordination of distributed service components), the exploitation of local knowledge only may not be enough. Nor can one think of concentrating in a single site or of replicating anywhere all available knowledge, especially when this knowledge represents dynamically evolving situations, i.e., it is subject to obsolescence. The compromise is to enable components which need more than simply local knowledge to organize and correlate distributed knowledge into sorts of networks that enable distributed components to "navigate" through the available knowledge to attain, on demand, the required degree of contextual awareness.

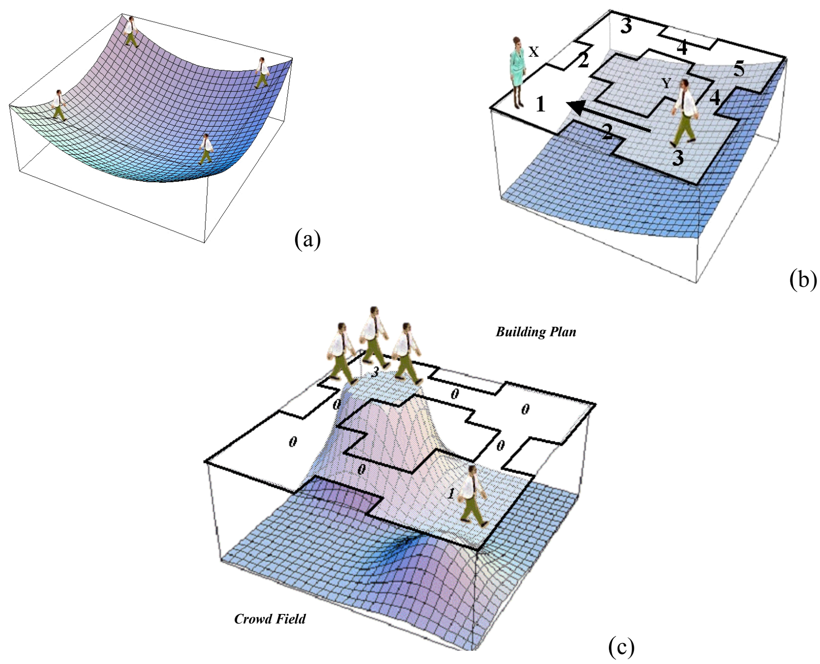

Figure 1: Schematic People-to-People and People-to-Environment Coordination.

From a third and final perspective, there is a recognized need for future autonomic communication scenarios to promote cross-layer interactions [5], which is of particular relevance for smart environments. This means that the service level and the network level cannot work as separated universes, each having its own goals. Rather, a continuous exchange of information must occur between the service and the network level, and vice-versa, so as to ensure that the overall activities of the system, at each level, will contribute towards the achievement of a satisfactory functioning. For this coordination and exchange of information to occur without significant interoperability issues, there must be some place where common information and valuable knowledge can be stored and can be properly organized so as to be accessible and understandable by both the network and the application levels.

2.1. Application Scenarios of Knowledge Networks

Consider a person, suffering from mild dementia, who has to go regularly to a health clinic at certain time intervals to retrieve specific treatment. The potential problem facing persons suffering from mild dementia is that they may not only forget the time and the place of the scheduled visit but upon arrival they may also forget the actual purpose of the visit. If a pervasive support environment could be established which would extend from the person's home to their intended destination (beyond the home) and could be supported via a simple mobile device, such as a PDA, this could be used to guide the person from a spatial perspective i.e. in providing directions and in providing cognitive reinforcement i.e. the purpose of the visit. For intelligent services to achieve such a behaviour it is necessary that individual components of autonomous smart environments become context-aware and exhibit self-management capabilities in order to achieve their objective.

This type of autonomous, situation-aware communication is depicted as an example in Figure 2. In this scenario a virtual orb surrounds a person entering a building and as such not only senses its immediate surroundings but may also interact with individual services provided throughout the smart environment. Such communication is not necessarily limited to the 'smart building' itself but could also communicate with any intelligent component thereof and of course individuals (family/friends/careers) that could provide specific help and guidance.

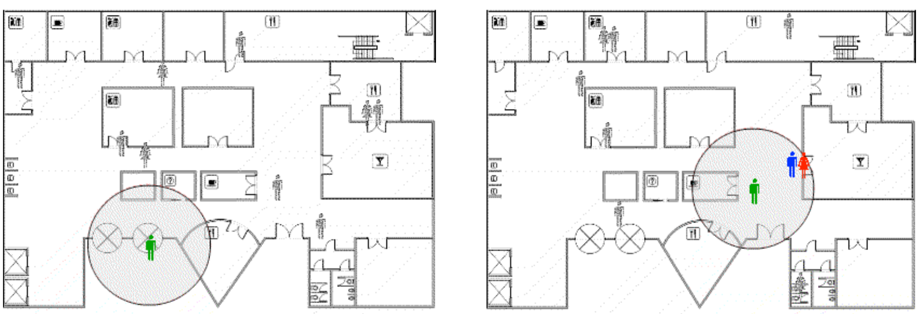

Figure 2: Examples of People-to-Environment Interaction with a smart environment.

Within this scenario the notions of spatial orientation reinforcement can be further exemplified; stakeholders within close proximity to the patient can be assessed to gain an appreciation for the level of support they may be able to offer. Consider the scenario as depicted in Figure 3. In this instance the patient is represented as the grey icon in the centre of the virtual orb with stakeholders who can offer any form of support as dark grey icons. Firstly, the service has identified that within the shopping centre there is one stakeholder who can provide orientation reinforcement (Figure 3 (a)). As the patient moves the service detects that there are now two further stakeholders who can provide support in instances of required cognitive reinforcement and two stakeholders who could provide orientation reinforcement. This is represented in Figure 3 (b) by the four dark grey icons now within the patient's virtual orb. The system has also identified a number of other stakeholders who may be likely to move into the proximity of the patient, but at present, have not been considered by the system to be in a position to offer assistance (coloured as light grey).

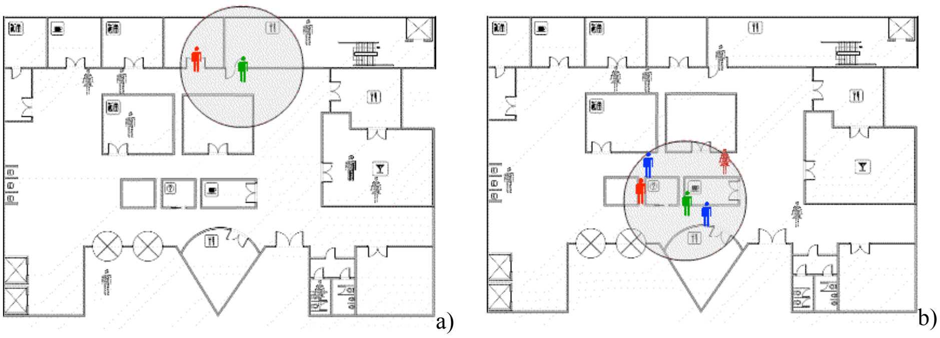

Figure 3: People-to-People Interaction (a) Patient can obtain support from one stakeholder (b) Patient can obtain support from four stakeholders.

2.2. *Knowledge Network Elements*

The aim of autonomic systems is to reduce the amount of maintenance and management needed to keep systems working as efficiently as possible, as much of the time as possible. It is about making systems self-managing for a broad range of activities. Such an autonomic middleware as described here provides an infrastructure for building adaptive applications that can deal with environment changes in person-centric smart environments.

According to [6], context is any information that can be used to characterise the situation of an entity (person or object) that is considered relevant to the interaction between a user and an application. A context-aware system [3] is capable of using context information, ensuring it successfully performs its expected role, and also maximises the perceived benefits of its use. Here for instance, self-contextualisation is the ability of a system to describe, use and adapt its behaviours to its context; meanwhile, it does not have to be aware of any other form of context knowledge. However, a context-aware system is a system that acts based on knowledge of a certain context. Network context for supporting service/software components should be made available, so that multiple service/software components may take advantage of the available network context (such as illustrated in Figure 4). In order to do so in the complex environment of our vision of person-centric services in pervasive spaces, the service/software component must be equipped with certain self-management capabilities so that it can make use of context information for other self-management tasks that depend on context information [7].

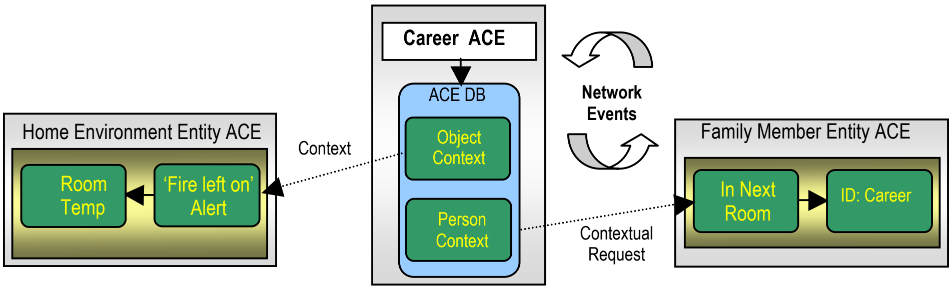

Figure 4: Contextual Information being shared by ACEs within a Smart Environment.

For instance in Figure 4, what we see is a career Autonomic Communication Element (ACE) communicating with another ACE belonging to both family member entities and the actual home environment in order to bring contextual information in the form of alerts (e.g. The fire in the front room has been left on) or that their daughter is in the next room therefore execute 'event x'. The benefits of a distributed knowledge network such as this are that it can bring modifications or extensions to itself by virtue of its own computation. It can 'think about itself', thus giving the possibility to enhance adaptability and to better control the applications that are based on top of it. By possessing the ability to 'think', we mean that significant benefits can be achieved in terms of monitoring key events (*inspection*), adapting components to changing circumstances (*adaptation*), and reconfiguring systems to meet new requirements (*extension*) [8]. Therefore ACEs possess the ability to observe the occurrence of arbitrary events in the underlying network, and ultimately allow each application to adapt the internal behaviour of the system, either by changing the behaviour of an existing service (e.g., tuning the implementation of message passing to operate more optimally over a wireless link), or dynamically reconfiguring the system (e.g., inserting a filter object to reduce the bandwidth requirements of a communications stream). Such steps are often the result of changes detected during inspection.

Pervasive person-centric computing environments consist of multitudes of heterogeneous devices, both stationary and mobile, with different and dynamic changing capabilities and specific ways to access them. One crucial device capability is the ability to communicate and interact with other devices such as in spontaneous networks with changing members due to the communication range [9]. To summarise, devices interact by forming spontaneous networks using different network interfaces and interoperability protocols. Membership in these networks is temporary and network related properties like communication cost and bandwidth change dynamically. Services in turn use device capabilities or further services, which are provided by either the local device, or by remote interaction with other devices. From the end-users point of view, one of the main challenges is to use services and capabilities with changing availability. Existing middleware platforms typically address portability of applications via standardised interfaces for remote service interaction, however, to create a compelling user experience, new knowledge network middleware needs to be deployed and optimised for such environments.

3. Conclusions

It is clear that technology can be deployed within the home environment, in the form of cognitive prosthetics, to improve the quality of life for those patients suffering from mild dementia. Services which can be offered centre around cognitive and social reinforcement in addition to functional support for daily activities. Mobile devices such as PDAs or smart phones have the technical and communications abilities to provide a platform upon which these services can be deployed. Nevertheless, to avoid reducing the net impact of these services it is essential to consider a means to offer a continuum of service once the patient leaves their home environment. In this study we have addressed this issue through the proposition of a knowledge network paradigm. Our work is underpinned by our previously developed concepts of gravitational fields within smart spaces. We have shown how with such an approach we can offer a continuum of service at a number of different levels of granularity for family/friends and healthcare providers to offer orientation and cognitive reinforcement respectively.

Acknowledgments

This work has been supported in part by the project CASCADAS (IST-027807) funded by the FET Program of the European Commission.

References

[1] Sterritt, R., M.D. Mulvenna, and A. Lawrynowicz, Dynamic and Contextualised Behavioural Knowledge in Autonomic Communications Proc. of the 1st IFIP Workshop on Autonomic Communications. Berlin: Springer-Verlag, 2004.

[2] Balkenius, C., Moren, J. A Computational Model of Context Processing, *6th International Conference on the Simulation of Adaptive Behaviour*. The MIT Press, 2000.

[3] Buchholz, T., Kupper, A. and Schiffers, S. Quality of context information: What is it is and why we need it, *Proceedings of the 10th HP-OVUA Workshop*, Geneva, Switzerland, July, pp. 112-120, 2003.

[4] Mamei, M., and F. Zambonelli, Field-based Coordination for Pervasive Multiagent Systems, Springer Verlag (Berlin, D), 2006.

[5] EU IST Commission, Situated and Autonomic Communication Initiative, FET Report, www.cordis.lu/ist/fet/comms.html, 2005.

[6] Dey, A.K. and Abowd, G.D. Towards a better understanding of context and context awareness, in Workshop on the What, Who, Where, When and How of Context-Awareness, affiliated with the 2000 *ACM Conference on Human Factors in Computer Systems (CHI 2000)*, The Hague, The Netherlands, April, pp.371-372, 2000.

[7] Serrat, J., Serrano, J.M., Justo, J., Marín, R., Galis, A., Yang, K., Raz, D. and Sykas, E.D. *An Approach to Context Aware Services*, NOMS2004 19–23 April, Seoul, Korea, 2004.

[8] Solon, A., Mc Kevitt, P. and Curran, K. 'TeleMorph: bandwidth determined mobile multimodal presentation', *Information Technology and Tourism*, February ISSN: 1098-3058, Cognizant Publishers, USA, Vol. 7, No. 1, pp.33–47, 2005.

[9] Becker C., Schiele, G., Gubbels, H., Rothermel, K. BASE - A Micro-broker-based Middleware For Pervasive Computing. *Proceedings of the IEEE International Conference on Pervasive Computing and Communication (PerCom),* Fort Worth, USA, July 2003.